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At Grenoble, France, the party was accompanied, at different times, by Professor Lory and Dr. Jacob of the University of Grenoble, and Professor de Martonne of the University of Lyons. With Grenoble as a centre, trips of from one to several days' duration were taken to the more striking or important examples of glacial and stream erosion and phenomena in that vicinity. Among the most interesting were examples of the diversion of streams from their wide pre-glacial valleys to their present deep, narrow, post-glacial gorges. In the valley leading from Le Bourg-d'Oisans to St. Christophe, landslide topography is abundant and well-developed and its close similarity to morainic topography is well shown; the most striking example being that of a lake of considerable extent formed by a barrier about 1,000 feet in height which was made by a post-glacial landslide.

A journey through the Grand Chartreuse was made to study the topography of a folded non-glaciated limestone region.

After a visit to the Cervennes of central France, where a well-developed peneplain is strongly trenched by streams, the party went to Le Puy in Auvergne, where are to be seen the unique forms which have resulted from the action of erosion upon igneous and pyroclastic rocks. Here the party disbanded, a part to go to Geneva to attend the Geographical Congress and the remainder to their homes.

The results of this extended excursion were, perhaps, no more valuable than a well-planned excursion of similar extent in our own country; but there were certain advantages, as, for example, an acquaintance with the geology and geography of a portion of another continent, and of certain regions which had been carefully worked out by eminent European geologists or geographers, as well as an acquaintance with European geographers and their methods of study.

Altogether, Professor Davis is to be congratulated upon this thoroughly successful outcome of his experiment.

THE FORTY-NINTH PARALLEL BOUNDARY LINE.

BY

G. W. LITTLEHALES.

Dr. Otto Klotz, Dominion Astronomer and Director of the Observatory at Ottawa, Can., has published, in the *Journal* of the Royal Astronomical Society of Canada (Dec., 1908), an interesting paper, entitled "The Forty-Ninth Parallel," in which he has stated the characteristics of the line resulting from the operations of demarcation of the boundary between the United States and Canada, from Minnesota to the Pacific Coast. He gives an impression of the arduous and protracted labours of the astronomers and surveyors who have, from time to time during the last half century, represented the two governments in designating the location of this frontier.

Many persons have, doubtless, wondered how it happens that Minnesota extends apparently into Canada, north of the 49th parallel, in the region of the Lake of the Woods. This is explained by the Convention entered into on October 20, 1818, between the United States and Great Britain, which says:

> "It is agreed that a line drawn from the most northwesterly point of the Lake of the Woods, along the forty-ninth parallel of north latitude, or, if the said point shall not be in the forty-ninth parallel of north latitude, then that a line drawn from the said point due north or south, as the case may be, until the said line shall intersect the said parallel of north latitude, and from the point of such intersection due west along and with the said parallel, shall be the line of demarcation between the territories of the United States and those of His Britannic Majesty, and that the said line shall form the northern boundary of the said territories of the United States, and the southern boundary of the territories of His Britannic Majesty, from the Lake of the Woods to the Stony Mountains" [Rocky Mountains].

This line is 860 miles long.

For the extension of this boundary from the Rocky Mountains to the Pacific Ocean, it is provided in Article I of the Treaty concluded at Washington on June 15, 1846, between the United States and Great Britain, that from the point on the

> "forty-ninth parallel of north latitude, where the boundary laid down in existing treaties and conventions between the United States and Great Britain terminates, the line of boundary between the territories of the United States and those of Her Britannic Majesty shall be continued westward, along said forty-ninth parallel of north latitude, to the middle of the channel which separates the continent from Vancouver's Island, and thence southerly through the middle of the said channel, and of Fuca's Straits, to the Pacific Ocean."

This line is 410 miles long, making a total of 1,270 miles along the 49th parallel.

Boundaries which are defined, like this one, by a parallel of latitude or a meridian of longitude, are known as astronomical frontiers in contradistinction to natural frontiers, such as mountain ranges or the shore of the ocean, and to those frontiers which are defined by some existing artificial feature or condition. While the astronomical frontier is capable of brief and precise description in a treaty, in a manner that will leave no doubt as to the meaning of the parties to the agreement, it has no local or topographical value until it is marked out upon the ground.

Since the agreement was that the boundary should be a parallel of latitude, it became necessary for the astronomers engaged in the demarcation to define what should be the meaning of the term latitude as used in the treaties. The astronomical latitude of a place has been defined as the declination of its zenith, or the angle between the plane of the equator and the direction of gravity at that place, however, that direction may be affected by local causes. The geocentric latitude, on the other hand, is the angle made at the centre of the earth between the plane of the equator and a line drawn from the observer to the centre of the earth, which line does not coincide with the direction of gravity since the earth is not spherical but ellipsoidal in form. The geographical or geodetic latitude of a station is the angle formed with the plane of the equator by a line drawn from the station perpendicular to the surface which the deductions of geodesists have assigned as the closest approximation of a mathematical figure to the form and size of the surface of the earth.

The astronomical and geographical latitudes do not differ much, and would evidently not differ at all if there were no local variations of gravity and if the mathematical figure assigned by geodesists were the actual form and size of the earth; but the geocentric latitude, which is used principally in certain astronomical calculations in which parallax is involved, differs from the others by a comparatively large amount.

For the determination of geocentric and of geographical or geodetic latitudes, the form and dimensions of the earth must be known, but the astronomical latitude is capable of determination directly from latitude observations. It was this property of the astronomical latitude that influenced the Commission, which was appointed to carry out the stipulations of the treaty, in deciding that the boundary to be traced between Minnesota and the Rocky Mountains should be a line connecting stations at each of which the direction of the force of gravity should make an angle of 49° with the plane of the equator. The effects of the irregular distribution of matter, both in the visible arrangement of the surface forms of the earth and in the varying densities of the materials below its crust, in altering the direction of gravity, are by no means insensible as compared with the accuracy of modern astronomical observations; but to have satisfied the condition that the sum of the differences of the astronomical and geodetic latitudes should be zero, and thus to have made the line of demarcation a mean parallel, would have entailed a revision of the whole work after the location of the astronomical stations and the completion of the triangulation between them.

The boundary traced upon the surface of the earth thus came to be an irregular curve known as an astronomical parallel of latitude. The recommendation for this, by the chief astronomers of the Commission, was based upon the following grounds: 1st, that the portion of the 49th degree parallel of latitude included within the operations of the Commission, being only about one-twentieth part of the entire circle of latitude, was not sufficient to fix, with mathematical accuracy, the true position of the mean parallel of 49°, and that, therefore, if such a parallel were described, depending upon the mean of the astronomical stations, no known point of the boundary would be in latitude 49°; 2nd, that as the amplitude of the arcs, included between the mean and astronomical parallels, would, in many cases, be very considerable, grave errors and complications might arise in the subsequent resurvey of any lost portion of the boundary; 3rd, that the definition of a mean line would involve a readjustment of the whole boundary, after the first careful survey was completed, and consequently a very considerable increase of expense without any corresponding practical benefit; 4th, that for every purpose, except that of geodetic computation, a parallel of points determined astronomically is a true parallel of latitude, and, therefore, fulfills the stipulations of the treaty.

The International Commission of 1872 established 40 astronomical stations at approximately equal intervals throughout the distance of 860 miles from the Lake of the Woods to the Rocky Mountains, and these, together with the 28 stations established by the earlier commission of 1857 along the stretch of 410 miles passing from the Rocky Mountains to the Pacific coast, have served as the basis for the tracing of the boundary line, although all of the extent of this frontier was not surveyed to form a connection between the boundary stations until the recent International Commission was organized for the purpose of completing and re-monumenting it.

For the part of the boundary east of the Rocky Mountains it was agreed that the line joining any two adjacent monuments should be an arc of the parallel of latitude; but, with reference to the western part, a different settlement had been reached between the earlier commissioners by which the connecting line between monuments should be a geodetic line or an arc of a great circle of the terrestrial spheroid. At each of the governing astronomical stations prime vertical circles were laid off upon the ground, and, from the line so traced, the calculated offsets to the small circle of latitude or to the geodesic line, as the case might be, were measured at convenient intervals. Wherever there was a relative deflection of the plumb line between two adjacent astronomical stations, the arcs of the boundary, thus traced with reference to the stations, would not meet, and the divergence was distributed between the two related boundary stations in such a manner as to bring about a closure between the successive parts of the boundary line.